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The Weight–Joint Damage Gradient: Association of Body Mass Index With Radiological Severity of Primary Knee Osteoarthritis in Adults

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Abstract

Background: Obesity is an important modifiable factor in primary knee osteoarthritis (POA) and may contribute to greater structural joint damage through increased mechanical loading and metabolic inflammation. This study evaluated the association between body mass index (BMI) and radiological severity of POA.

Methods: A prospective cross-sectional study was conducted in the Department of Orthopaedics, Kerala Medical College, Mangode, Palakkad, from May 2025 to January 2026. A total of 114 adults with POA were included. BMI was calculated and categorized as normal, overweight or obese. Radiological severity was assessed using the Kellgren–Lawrence (KL) grading system. Associations between BMI and KL grade were analysed using chi-square test and one-way ANOVA.

Results: The mean age was 58.7 ± 9.4 years, and 59.6% were females. Mean BMI was 27.8 ± 4.2 kg/m². Obesity increased progressively from 5.6% in KL grade 1 to 72.7% in grade 4. BMI category was significantly associated with radiological severity (χ^2=34.31, p<0.001). Mean BMI increased from 23.8 ± 2.8 kg/m² in grade 1 to 31.4 ± 3.8 kg/m² in grade 4 (F=21.27, p<0.001).

Conclusion: Increasing BMI was strongly associated with greater radiological severity of POA. Weight optimization may therefore represent an important component of comprehensive OA management.

Keywords: Body mass index; Kellgren–Lawrence grading; Knee osteoarthritis; Obesity; Radiological severity

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Introduction:

Primary knee osteoarthritis (POA) is a degenerative joint disorder and an important cause of pain, impaired mobility and disability among adults. Increasing body mass index (BMI) is a potentially modifiable factor that may influence structural severity of knee osteoarthritis through greater mechanical loading across the tibiofemoral joint and obesity-related metabolic inflammation. Indian evidence has demonstrated higher BMI among patients with POA compared with controls, supporting an association between excess body weight and disease occurrence [1]. Recent Indian studies have also emphasized the value of radiographic assessment using the Kellgren–Lawrence grading system for determining structural severity and documenting disease progression [2, 3]. However, the relationship between increasing BMI categories and radiological severity remains important because identification of an association could strengthen weight-control strategies as part of osteoarthritis (OA) prevention and management. Therefore, the present study aimed to assess the association between BMI and radiological severity of POA in adults.

Methods:

A prospective cross-sectional observational study was conducted in the department of Orthopaedics, Kerala Medical College, Mangode, Palakkad, from May 2025 to January 2026. Adult patients presenting to the orthopaedic outpatient department with clinical features suggestive of POA were screened for eligibility and enrolled consecutively after obtaining written informed consent. Patients aged 40 years and above with knee pain, stiffness or functional limitation and radiological evidence of POA were included. Patients with secondary OA due to previous trauma, inflammatory arthritis, rheumatoid arthritis, gout, septic arthritis, congenital or developmental deformities, previous major knee surgery, intra-articular fracture, malignancy involving the knee, or other conditions that could significantly alter joint morphology were excluded. Patients with incomplete clinical or radiological data were also excluded. Demographic and clinical details including age, sex, duration of symptoms, laterality of knee involvement, history of comorbid illnesses and relevant treatment history were recorded using a structured proforma. Height was measured without footwear using a stadiometer to the nearest centimetre, and body weight was measured using a calibrated digital weighing scale to the nearest kilogram. Body mass index was calculated as weight in kilograms divided by the square of height in metres (kg/m²). Participants were classified according to BMI into underweight, normal weight, overweight and obese categories using standard BMI criteria. For patients with

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bilateral knee involvement, each knee was clinically evaluated, while the knee with greater radiological severity was considered for the primary patient-level analysis. All participants underwent standardized weight-bearing anteroposterior radiographs of the affected knee, with additional lateral and skyline views obtained whenever clinically indicated.

Radiographs were assessed for joint-space narrowing, osteophyte formation, subchondral sclerosis and bony deformity. Radiological severity of OA was graded according to the Kellgren–Lawrence classification as grade 0, no radiological changes; grade 1, doubtful joint-space narrowing with possible osteophyte formation; grade 2, definite osteophytes with possible joint-space narrowing; grade 3, multiple osteophytes, definite joint-space narrowing, sclerosis and possible bony deformity; and grade 4, marked joint-space loss, severe sclerosis, large osteophytes and definite bony deformity. For analysis, participants were further grouped according to increasing radiological severity. The primary outcome was the association between BMI and Kellgren–Lawrence grade of POA. Data were entered into Microsoft Excel and analysed using appropriate statistical software. Continuous variables were summarized as mean with standard deviation or median with interquartile range depending on distribution, whereas categorical variables were presented as frequency and percentage. Differences in mean BMI across radiological grades were assessed using one-way analysis of variance or the Kruskal–Wallis test, as appropriate. Associations between BMI categories and OA severity were evaluated using the chi-square test or Fisher's exact test. Correlation between BMI and radiological grade was assessed using Spearman's rank correlation, and a p-value <0.05 was considered statistically significant.

Results:

The study included 114 adults with POA, with a mean age of 58.7 ± 9.4 years. Females constituted 59.6% of the participants. The overall mean BMI was 27.8 ± 4.2 kg/m²; 41.2% were overweight and 36.8% were obese (Table 1). Radiologically, Kellgren–Lawrence grade 3 was the most frequent grade, observed in 39 (34.2%) participants, followed by grade 2 in 35 (30.7%), grade 4 in 22 (19.3%) and grade 1 in 18 (15.8%). A progressive increase in the proportion of obesity was observed with increasing radiological severity. Obesity was present in only 5.6% of patients with grade 1 disease but increased to 20.0% in grade 2, 46.2% in grade 3 and 72.7% in grade 4 disease. The association between BMI category and Kellgren–Lawrence grade was statistically significant ($\chi^2 = 34.31$, $p < 0.001$) (Table 2). Mean BMI also increased progressively from 23.8 ± 2.8 kg/m² in grade 1 to 31.4 ± 3.8 kg/m² in grade 4. One-way ANOVA demonstrated a significant difference in mean BMI across radiological grades ($F = 21.27$, $p < 0.001$), with a large effect size ($\eta^2 = 0.37$) (Table 3).

Discussion:

The present study demonstrated a clear association between increasing body mass index and greater radiological severity of POA. Among the 114 participants, the mean age was 58.7 ± 9.4 years, 59.6% were women, and the mean BMI was 27.8 ± 4.2 kg/m². More than three-fourths of the study population was either overweight or obese, indicating that excess body weight was highly prevalent among adults presenting with knee OA. Grade 3 disease was the most frequent radiological category, followed by grades 2 and 4. Recent Indian epidemiological evidence confirms the substantial burden of knee OA: Hazra et al. reported a pooled prevalence of approximately 20% across Indian population-based studies, while Daniel et al. estimated a prevalence of 47% among elderly Indians [4, 5]. The female predominance in the present study was also consistent with Indian observations. Ratan et al., in a tertiary-care study from AIIMS Bhopal, found that women with knee OA experienced significantly greater pain, stiffness and functional impairment than men, despite comparable radiographic grading [6]. Tawade et al. further demonstrated progressive deterioration in knee structure and lower-extremity function with increasing OA severity in an Indian cohort [7]. These observations emphasize that knee OA represents a multidimensional disorder in which age, sex, body composition, biomechanics and functional capacity interact with structural disease severity.

The most important finding of the present study was the progressive increase in obesity with advancing Kellgren–Lawrence grade. Only 5.6% of participants with grade 1 disease were obese, compared with 20.0% in grade 2, 46.2% in grade 3 and 72.7% in grade 4. The association between BMI category and radiological severity was highly significant ($\chi^2 = 34.31$, $p < 0.001$). Mean BMI similarly increased from 23.8 ± 2.8 kg/m² in grade 1 to 31.4 ± 3.8 kg/m² in grade 4, with a statistically significant difference across grades ($F = 21.27$, $p < 0.001$). This graded relationship is biologically plausible because greater body weight increases compressive forces transmitted through the tibiofemoral and patellofemoral compartments during standing, walking and stair climbing. Repetitive excessive loading may accelerate cartilage wear, joint-space narrowing, subchondral sclerosis and osteophyte formation. Indian biomechanical research supports the importance of abnormal loading in disease severity. Jain et al. demonstrated that alterations in knee geometry, particularly the metaphysio-diaphyseal angle, were significantly associated with increasing KL grade, emphasizing the importance of load distribution in radiographic progression [8]. Barai et al. found

important alterations in gait and functional knee parameters with progression of POA in an Indian population [2], while Tanpure et al. demonstrated measurable gait and biomechanical differences among adults with advanced OA [9]. Thus, the present association between BMI and radiological severity may partly reflect the cumulative mechanical consequences of excess weight acting on an already biomechanically vulnerable knee.

Radiological assessment remains essential for demonstrating structural OA, although radiographic abnormalities do not always parallel the patient's subjective symptoms. Shinde et al. studied 116 Indian patients using weight-bearing radiographs and KL grading and observed that radiological severity did not show a significant correlation with pain intensity, illustrating the potential discordance between structural changes and clinical symptoms [3]. The present study focused specifically on the relationship between BMI and structural severity rather than pain, thereby providing a more objective assessment of the association of excess body weight with established radiographic damage. The radiographic technique itself may influence apparent severity. Arun Kumar et al. reported that single-leg weight-bearing radiographs reduced measured medial joint-space width compared with conventional bilateral standing views and resulted in upgrading of KL severity in approximately half of their patients [10]. Similarly, Mulpur et al. demonstrated considerable variation in coronal alignment phenotypes among Indian osteoarthritic knees, highlighting the complex relationship between knee anatomy, alignment and degenerative changes [11]. Beyond mechanical loading, obesity may also influence OA through metabolic mechanisms. Adipose tissue is biologically active and can contribute to systemic low-grade inflammation and metabolic dysregulation. Arjun et al., in an Indian systematic review of metabolomics in knee OA, identified alterations involving lipid metabolism, glycolysis and the tricarboxylic acid cycle, suggesting that metabolic disturbances may contribute to OA pathogenesis and progression [12]. Therefore, the observed BMI–severity relationship is likely to represent a combination of increased mechanical stress and obesity-associated metabolic effects rather than load alone.

The clinical relevance of these findings lies in the modifiable nature of excess body weight. Unlike age, sex or constitutional knee alignment, BMI can potentially be altered through dietary intervention, physical activity and structured weight-management programmes. Early identification of overweight and obese adults with knee symptoms may therefore provide an opportunity to reduce mechanical loading before advanced radiological changes develop. Nutritional status should, however, be interpreted comprehensively rather than through BMI alone. Maheshwari et al. demonstrated a substantial burden of nutritional abnormalities among Indian patients with knee OA and emphasized the importance of nutritional assessment as part of clinical management [13]. The present findings consequently support incorporating BMI assessment and appropriate weight-management counselling into routine evaluation of POA. Nevertheless, because the present investigation was cross-sectional, the observed association cannot establish that elevated BMI directly caused radiological progression; reverse effects are also possible because severe OA may reduce mobility and promote weight gain. Other potential confounding variables such as occupational loading, physical activity, muscle strength, limb alignment, metabolic disease and duration of obesity were not fully quantified. Longitudinal Indian studies following patients across BMI categories with repeated standardized weight-bearing radiographs would therefore be valuable. Despite these limitations, the strong stepwise increase in both obesity prevalence and mean BMI across KL grades indicates that increasing BMI is closely associated with greater radiological severity of POA and reinforces weight optimization as an important component of comprehensive OA management.

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Table 1: Baseline characteristics of the study participants

Characteristic	Value
Age, years, Mean ± SD	58.7 ± 9.4
Male	46 (40.4%)
Female	68 (59.6%)
Duration of knee symptoms, years, Median (IQR)	3.0 (2.0–5.0)
BMI, kg/m², Mean ± SD	27.8 ± 4.2
Normal BMI (18.5–24.9 kg/m²)	25 (21.9%)
Overweight (25.0–29.9 kg/m²)	47 (41.2%)
Obese (≥30 kg/m²)	42 (36.8%)
Kellgren–Lawrence grade 1	18 (15.8%)
Kellgren–Lawrence grade 2	35 (30.7%)
Kellgren–Lawrence grade 3	39 (34.2%)
Kellgren–Lawrence grade 4	22 (19.3%)

Table 2: Association between BMI category and radiological severity of POA

Kellgren–Lawrence grade	Normal n (%)	Overweight n (%)	Obese n (%)	Total
Grade 1	10 (55.6)	7 (38.9)	1 (5.6)	18
Grade 2	10 (28.6)	18 (51.4)	7 (20.0)	35
Grade 3	4 (10.3)	17 (43.6)	18 (46.2)	39
Grade 4	1 (4.5)	5 (22.7)	16 (72.7)	22
Total	25 (21.9)	47 (41.2)	42 (36.8)	114
$\chi^2 = 34.31$; $P<0.001$				

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Table 3: Comparison of mean BMI according to Kellgren–Lawrence grade		
Kellgren–Lawrence grade	**n**	**BMI, Mean ± SD**
Grade 1	18	23.8 ± 2.8
Grade 2	35	26.2 ± 3.1
Grade 3	39	29.1 ± 3.6
Grade 4	22	31.4 ± 3.8
Overall	114	27.8 ± 4.2
F value = 21.27; P <0.001		